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MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING CHARACTERISTICS OF A 1/30-SCALE

MODEL OF THE GRUMMAN WF-2 AIRPLANE

TED NO. NASA AD 3134

By Henry A. Lee

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NATIONAL AERONAUTICS AND
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231

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SUMMARY

An investigation was conducted in the Langley 20-foot free-spinning tunnel on a 1/30-scale model of the Grumman WF-2 airplane. The effects of control settings and movements upon the erect-spin and recovery characteristics for the flight gross-weight loading with normal center-of-gravity and rearward center-of-gravity positions were determined. For the inverted-spin tests, the flight gross-weight loading with normal center-of-gravity position was used. Brief tests were also made with the radome removed to determine the effect of the radome on the spin and recovery characteristics of the airplane.

The results of the tests of the model indicate that erect spins of the airplane in the flight gross-weight loading with the normal (26.3-percent mean aerodynamic chord) center-of-gravity position and with the most rearward (30-percent mean aerodynamic chord) center-of-gravity position possible will be satisfactorily terminated by full rudder reversal to against the spin accompanied by movement of the elevator to at least two-thirds down. With the radome removed, the spin will be steeper and considerably more oscillatory than with the radome on. Recoveries by the preceding technique will be satisfactory. Inverted spins of the airplane will be satisfactorily terminated by full rudder reversal followed by neutralization of the longitudinal and lateral controls.

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*Title, Unclassified.

INTRODUCTION

In accordance with the request of the Bureau of Aeronautics, Department of the Navy, an investigation was made in the Langley 20-foot free-spinning tunnel to determine the spin and recovery characteristics of a 1/30-scale model of the Grumman WF-2 airplane. The WF-2 airplane is a high-wing, twin-engine aircraft of conventional configuration with twin vertical tails and a large radome installed above the fuselage.

The erect-spin and recovery characteristics of the model were determined for the flight gross-weight loading with normal center-of-gravity position and for the flight gross-weight loading with the most rearward center-of-gravity position. For the normal center-of-gravity position, tests were made with the large radome removed to determine the effects of the radome on the spin and recovery characteristics. The inverted-spin and recovery characteristics of the model with the radome installed were determined for the flight gross-weight loading with normal center-of-gravity position.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations of model mass characteristics occurring during tests, and a general comparison between model and airplane results.

SYMBOLS

b	wing span, ft
S	wing area, sq ft
c	wing or elevator chord at any station along the span, ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs

I_X, I_Y, I_Z moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2

$$\frac{I_X - I_Y}{mb^2}$$ inertia yawing-moment parameter

$$\frac{I_Y - I_Z}{mb^2}$$ inertia rolling-moment parameter

$$\frac{I_Z - I_X}{mb^2}$$ inertia pitching-moment parameter

ρ air density, slugs/cu ft

μ relative density of airplane, $m/\rho Sb$

α angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ angle between span axis and horizontal, deg

V full-scale true rate of descent, ft/sec

Ω full-scale angular velocity about spin axis, rps

MODEL

The 1/30-scale model of the Grumman WF-2 airplane was furnished by the Bureau of Aeronautics, Department of the Navy, and was prepared for testing by the Langley Research Center of the National Aeronautics and Space Administration. A three-view drawing of the model tested is shown in figure 1. A photograph showing the model in the normal flying configuration is shown in figure 2. The dimensional characteristics of the airplane are presented in table I.

The model was ballasted to obtain dynamic similarity to the airplane at an altitude of 30,000 feet (ρ = 0.000889 slug/cu ft). This high altitude was necessary for correct ballasting because of the relatively heavy construction of the model. Mass characteristics and mass parameters for loadings possible on the airplane and for the loading conditions tested on the model are presented in table II. A remote-control mechanism was

installed in the model to actuate the controls for the recovery attempts. Sufficient torque was exerted on the controls for the recovery attempts to reverse them fully and rapidly.

The normal, maximum control deflections used on the models during the tests (measured perpendicular to the hinge lines) were:

Rudder, deg . . . . 25 right, 25 left
Elevator, deg . . . . 30 up, 15 down
Ailerons, deg . . . . 20 up, 15 down

RESULTS AND DISCUSSION

The results of the spin tests of the model are presented in charts 1 through 4. The model data are presented in terms of full-scale values for the airplane at an altitude of 30,000 feet. On the basis of spin-tunnel experience, the current results are believed to be somewhat more conservative than corresponding results which would be obtained at a lower altitude. During the test, the model spun more readily to the left than to the right; therefore, the model results are presented in terms of left spins. Propellers were not simulated on the model, but on the basis of spin-tunnel experience, the results presented are felt to be generally applicable for the airplane spinning either to the right or to the left with idling propellers. Because of the gyroscopic effects of twin propellers turning clockwise (as viewed from pilot's seat) the airplane right spins may, however, be slightly steeper than corresponding left spins.

Erect Spins

The results of erect-spin tests performed to the pilot's left for the model in the flight gross-weight loading with the normal (26.3-percent $\bar{c}$) center-of-gravity position (loading 2 in table II) are presented in chart 1. The spins obtained were generally very steep with a rather fast rate of rotation. The data presented indicate that for all control settings tested, satisfactory recoveries were obtained by reversal of the rudder to full against the spin. Unsatisfactory recoveries were obtained from the criterion spin (ailerons one-third with the spin and elevators full up) when the rudder was reversed to two-thirds (17°) against the spin. However, satisfactory recoveries were obtained by reversing the elevator from full up to two-thirds (10°) down simultaneously with rudder reversal to two-thirds against the spin and also by rudder reversal alone to 20° against the spin. Lateral controls with the spin (stick right in a right spin) had a slight adverse effect,

whereas lateral control against the spin was slightly favorable for recovery. The results obtained are consistent with reference 1 for the design loading in which the weight is approximately equally distributed about the X and Y axes. The recommended recovery technique for spins of the airplane with this loading is full rudder reversal to against the spin followed after approximately one-half turn by downward movement of the elevator. On recovery, when the rudder was reversed to against the spin, the model went into a very steep or vertical dive after the spin rotation stopped; and when elevators were also deflected down for recovery, the model became inverted in the dive or went into an inverted spin. Therefore, after the spin rotation stops, the controls should immediately be moved to prevent the airplane from diving too steeply and going into an inverted dive or an inverted spin. The rudder should be neutralized, and the stick pulled back enough to prevent the rapid build up of airspeed from the dive.

Chart 2 presents the spin results when the center of gravity was moved back to 30-percent $\bar{c}$, the most rearward center-of-gravity position that can be obtained on the airplane (loading 3 in table II). The results indicated that the spins obtained were generally a little steeper than for the normal center-of-gravity position, and the recoveries obtained by rudder reversal were similar. Therefore, it is believed that in the criterion spin (ailerons deflected one-third with the spin and elevators set full up) any control movement used to obtain satisfactory recoveries for the spins with normal center-of-gravity position will also be satisfactory for the spins with rearward center-of-gravity position. The recommended recovery technique for spins of the airplane for all loading conditions is, therefore, full rudder reversal to against the spin followed by approximately one-half turn by downward movement of the elevator.

In order to evaluate the effect of the large radome on the spin and recovery characteristics of the model, brief tests were made with the radome removed. These tests are represented in chart 3. The results of these tests indicate that with the radome removed the spin of the model was somewhat steeper and considerably more oscillatory than with the radome on. Recoveries by rudder reversal were a little faster with the radome off than on, and satisfactory recoveries were obtained in the criterion spin (aileron one-third with and elevator full up) by reversing the rudder from full with to two-thirds against the spin.

Inverted Spins

The results of inverted-spin tests of the model are presented in chart 4. The order used for presenting the data for inverted spins is different from that used for erect spins. For inverted spins, controls crossed for the established spin (right rudder pedal forward and stick

to the pilot's left for a spin with rotation to the pilot's right) is presented to the right of the chart, and stick back is presented at the bottom. When the controls are crossed in the established spin, the ailerons aid the rolling motion; when the controls are together, the ailerons oppose the rolling motion. The angle of wing tilt ϕ in the chart is given as up or down relative to the ground.

The tests were made for the flight gross-weight loading with the normal (26.3 percent $\bar{c}$) center-of-gravity position. The results indicate that the spins were generally steep with a fast rate of rotation. The flattest spins were obtained with the ailerons set with the spin (controls crossed) and elevator full up (stick forward). Satisfactory recoveries were obtained from the criterion spin by reversing the rudder to one-third against the spin, but satisfactory recoveries could not be obtained by rudder neutralization. The recommended technique for recovery from inverted spins for all loading conditions is to reverse the rudder to full against the spin and to neutralize the lateral and longitudinal controls.

Landing Condition

The landing condition was not investigated on the model inasmuch as current Navy specifications do not require airplanes to be spin-demonstrated in the landing condition. Recovery characteristics in the landing condition may be of significant importance, however, because stall tests of an airplane generally made at altitude in the landing condition early during the flight-test program may result in an inadvertent spin. Analysis indicates that although recoveries from fully developed spins may be unsatisfactory (based on the study presented in ref. 2 of the results of tests of many models with landing gear and flaps extended and retracted), the WF-2 airplane should recover satisfactorily from an incipient spin in the landing condition. If a spin is inadvertently entered in the landing condition, the flaps and landing gear should be retracted, and recovery attempted immediately.

Recommended Recovery Technique

On the basis of results obtained with the model, the following recovery technique is recommended for all loadings and conditions of the airplane:

For erect spins, the rudder should be reversed to full against the spin, and approximately one-half turn later the elevator should be moved to at least two-thirds down. After the airplane has stopped spinning, the controls should be moved to prevent the airplane from diving too steeply and going inverted or into an inverted spin.

For recovery from inverted spins, the rudder should be reversed to full against the spin, and the lateral and longitudinal controls should be neutralized.

SUMMARY OF RESULTS

On the basis of results of tests of a 1/30-scale model of the Grumman WF-2 airplane, the following conclusions regarding the spin and recovery characteristics of the airplane at an altitude of 30,000 feet are made:

1. The spin-recovery characteristics of the airplane will be satisfactory from erect spins for all loadings possible on the airplane by rapid rudder reversal from full with to full against the spin and approximately one-half turn later movement of the elevator to at least two-thirds down.

2. Removal of the radome for erect spins will lead to steeper and more oscillatory spins. Satisfactory recoveries will be obtained by use of the preceding recovery technique.

3. Satisfactory recoveries will be obtained from any inverted spin by full rudder reversal to against the spin followed by neutralization of the longitudinal and lateral controls.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., February 2, 1959.

APPENDIX

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 3 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising air stream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 3.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with movement of ailerons to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and the dimensional characteristics of the model (refs. 1 and 4). Tests are also performed to evaluate the possible adverse effects on recovery of small deviations from the normal control configuration for spinning. For these tests, the elevator is set at full-up deflection, and the lateral controls are set at one-third of full deflection in the direction conducive to slower recoveries, which is with the spin (stick right in a right spin) for the WF-2. Recovery is attempted by rapidly reversing the rudder from full with the spin to only two-thirds against the spin, by simultaneous rudder reversal to two-thirds against the spin and movement of the elevator to either neutral or two-thirds down, or by simultaneous rudder reversal to two-thirds against the spin and stick movement to two-thirds with the spin. This control configuration and manipulation is referred to as the "criterion spin," with the particular control settings and manipulation used being dependent on the mass and the dimensional characteristics of the model.

Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from the criterion spin in any of the manners previously described is

accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, >300 fps, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. A recovery of 10 or more turns is indicated by ∞. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg . . . . ± 1
ϕ, deg . . . . ± 1
V, percent . . . . ± 5
Ω, percent . . . . ± 2

Turns for recovery obtained from motion-picture records . . . . . . $\pm\frac{1}{4}$

Turns for recovery obtained visually . . . . $\pm\frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent . . . . ±1
Center-of-gravity location, percent $\bar{c}$ . . . . ±1
Moments of inertia, percent 5

Controls are set with an accuracy of ±1°.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the Grumman WF-2 model varied from the true scaled-down values within the following limits:

Weight, percent . . . .   0 to 1 high

Center-of-gravity location, percent $\bar{c}$ . . . . . 1 forward to 1 rearward

Moments of inertia:
  I_X, percent . . . .   7 high to 9 high
  I_Y, percent . . . . 23 high to 36 high
  I_Z, percent . . . .   2 high to 10 high

Comparison Between Model and Airplane Results

The comparison between model and full-scale results in reference 5 indicated that free-spinning-tunnel tests of models, properly interpreted, can give good indications of the probable spin and recovery characteristics of corresponding airplanes and have proven to be extremely reliable as a means of determining optimum-control technique for best recovery from spins.

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L
3
2
6

TABLE I.- DIMENSIONAL CHARACTERISTICS OF THE

GRUMMAN WF-2 AIRPLANE

Overall length, ft 44.50

Wing:
  Area (including 47 sq ft in fuselage), sq ft 506.00
  Span, ft 72.395
  Root chord, in. 119.01
  Tip chord, in. 48.00
  $\bar{c}$, in. 88.53
  Leading edge $\bar{c}$ rearward leading-edge root chord, in. 12.90
  Aspect ratio 10.36
  Taper ratio 0.40
  Dihedral:
    Center line to fold joint, deg 2.5
    Fold joint to outboard, deg 4.0
  Incidence, deg 1.5
  Leading-edge sweepback, deg 4.08
  Airfoil section:
    Root . . . . NACA 63(215)A420 modified
    Tip . . . . NACA 63_2 A415

Horizontal tail:
  Area, sq ft 115.512
  Span, ft 24.95
  Root chord, in. 69.99
  Tip chord, in. 42.51
  Airfoil section . . . . NACA 64_2 A415 inverted camber
  Elevator area, rearward of hinge line, total, sq ft 25.88

Vertical tail:
  Area (total), sq ft 152.10
  Height, ft 9.50
  Stub fin:
    Area, sq ft 60.300
    Airfoil section . . . . NACA 66_2-015 modified
  Outboard fin:
    Area (including rudder), sq ft 91.80
    Root chord, in. 68.01
    Tip chord, in. 48.51
  Rudder area (total), sq ft 40.80

Radome:
  Length, ft 28.50
  Width, ft 19.25

L-326

TABLE II.- MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE

GRUMMAN WF-2 AIRPLANE AND FOR THE LOADINGS TESTED ON THE 1/30-SCALE MODEL

[Values given are full scale; moments of inertia are given about the center of gravity]

Loading	Weight, lb	Center-of-gravity location		Relative density, μ, at -		Moments of inertia, slug-ft^2			Mass parameters		
		$x/\bar{c}$	$z/\bar{c}$	Sea level	30,000 ft	I_X	I_Y	I_Z	$\dfrac{I_X - I_Y}{mb^2}$	$\dfrac{I_Y - I_Z}{mb^2}$	$\dfrac{I_Z - I_X}{mb^2}$
Airplane											
1 - Flight gross weight, most forward c.g.	24,800	0.220	0.312	8.841	23.649	58,815	53,795	103,065	12×10^{-4}	-122×10^{-4}	110×10^{-4}
2 - Flight gross weight, normal c.g.	24,800	0.263	-0.314	8.841	23.649	58,782	53,302	102,660	13×10^{-4}	-122×10^{-4}	109×10^{-4}
3 - Flight gross weight, most rearward c.g.	24,800	0.300	-0.311	8.841	23.649	58,839	55,301	104,530	9×10^{-4}	-122×10^{-4}	113×10^{-4}
Model											
2 - Flight gross weight, normal c.g.	24,989	0.259	-0.189	8.909	23.832	62,680	65,538	104,929	-7×10^{-4}	-97×10^{-4}	104×10^{-4}
3 - Flight gross weight, most rearward c.g.	25,000	0.305	-0.268	8.913	23.843	64,047	78,624	121,154	-36×10^{-4}	-104×10^{-4}	140×10^{-4}

CHART 1.– SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane WF-2	Attitude Erect	Spin direction simulated	Loading _2_ (see table _II_) Flight Gross Weight Loading Normal C.G.	Radome On
Slats	Altitude 30,000 ft	Left	Desired center-of-gravity position 26.3 percent c̄	

Model values converted to full scale　　　　　U—inner wing up　　D—inner wing down

30	1U
399	0.39
	$\frac{1}{2}$
a >6,	a >8

Ailerons $\frac{1}{3}$ With

33	1D
358	0.37
$\frac{3}{4}$,	$\frac{3}{4}$
a >8,	a ∞

34	2D
326	0.41
$\frac{1}{2}$, 1	
b $\frac{3}{4}$, b 2, b >2$\frac{1}{2}$	
c $\frac{3}{4}$, c 1, c 1$\frac{1}{2}$	
de 1, de 1	
a >8, a ∞	

33	2D
342	0.38
1, 1	
a ∞	

Ailerons $\frac{1}{3}$ Against

32	1U
358	0.39
b $\frac{3}{4}$, b 1	

33	1D
318	0.40
b $\frac{3}{4}$, b 1, b 1$\frac{1}{2}$	

Elevator $\frac{2}{3}$ Up

Elevator Full Up (Stick Back)

26	4U
373	0.51
$\frac{3}{4}$, 1	

←　Ailerons Full Against　(Stick Right)

34	1U
310	0.44
e 1$\frac{1}{4}$, 1$\frac{1}{4}$, 1$\frac{1}{2}$	

Ailerons Full With　(Stick Left)　→

Elevator Full Down (Stick Forward)

38	4U
270	0.41
e 1, f 1$\frac{1}{4}$	

38	2U
302	0.46
e 1, f 1	

38	1U
302	0.48
f 1$\frac{1}{4}$, f 1$\frac{1}{4}$	

a　Recovery attempted by reversing elevator from full up to 2/3 down.
b　Recovery attempted by rudder reversal to 2/3 against the spin.
c　Recovery attempted by rudder reversal to 20° against the spin.
d　Recovery attempted by reversing elevator from full up to 2/3 down simultaneously with rudder reversal to 2/3 against the spin.
e　Model recovered in an inverted dive.
f　Model recovered inverted and entered an inverted spin.

α (deg)	φ (deg)
v (fps)	Ω (rps)
Turns for recovery	

CHART 2.—SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane WF-2	Attitude Erect	Spin direction simulated Left	LOADING 3 (see table II) Flight Gross Weight Loading Most Aft C.G.	
Slats	Altitude 30,000 ft.		Desired center-of-gravity position 30.0 percent $\bar{c}$	Radome On

Model values converted to full scale   U-inner wing up   D-inner wing down

Ailerons ⅓ With

27	2D
365	0.30
½, ½	

32	4D
358	0.30
¾, 1, >1¼	

28	2D
365	0.32
½, ¾, ¾	
>1[a], >2¼[a]	

30	4D
350	0.32
1¼, 1¼	

27	2D
350	0.34
¾[a], 1[a]	

Elevator Full Up (Stick Back)

Elevators ⅔ Up

27	1U
365	0.42
½, ½	

Ailerons Full Against (Stick Right)

26	1U
373	0.44
1[b], ½[b]	

Ailerons Full With (Stick Left)

31	2D
335	0.42
1[c], 1[c]	

Elevator Full Down (Stick Forward)

27	2U
350	0.44
¾[b], ¾[b]	

31	0
358	0.46
1[b], 1¼[b]	

27	2D
335	0.49
1¼[c], 1¼[c]	

a Recovery attempted by rudder reversal to 2/3 against the spin.
b Model recovered in an inverted dive.
c On recovery model went into an inverted spin.

α (deg)	ϕ (deg)
V (fps)	Ω (rps)
Turns for recovery	

L-326

CHART 3 .—SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]

Airplane WP-2	Attitude Erect	Spin direction simulated	LOADING 2 (see table II) Flight gross weight loading normal C.G.	
Slats	Altitude 30,000 ft.	Left	Desired center-of-gravity position 26.3 percent c̄	Radome Removed

Model values converted to full scale   U–inner wing up   D–inner wing down

Ailerons
⅓ With

a
>416	
¼ , ¼	

a
310 416	
¾ , ½	

a
310 391	
b 1 , b 2	

a
310 391	
½ , ¾	

Elevator Full Up (Stick Back)

Ailerons Full Against (Stick Right) ←

a
19 59	23U 12D
310 416	0.46 0.91
c 1¼ , c 1

→ Ailerons Full With (Stick Left)

a
20 58	10U 17D
310 391	0.33 0.57
c ¾ , c ¾

Elevator Full Down (Stick Forward)

a
310 391	
d 1 , c 1	

a Very oscillatory and whipping type spin. Range or average values given. The steep phase of the spin has the fastest rate of rotation.
b Recovery attempted by rudder reversal to 2/3 against the spin.
c Recovered in an inverted dive.
d Recovered in an inverted spin.

α (deg)	φ (deg)
v (fps)	Ω (rps)
Turns for recovery	

CHART 4.-SPIN AND RECOVERY CHARACTERISTICS OF THE MODEL

[Recovery attempted by full rudder reversal unless otherwise noted (recovery attempted from, and developed-spin data presented for, rudder-full-with spins)]
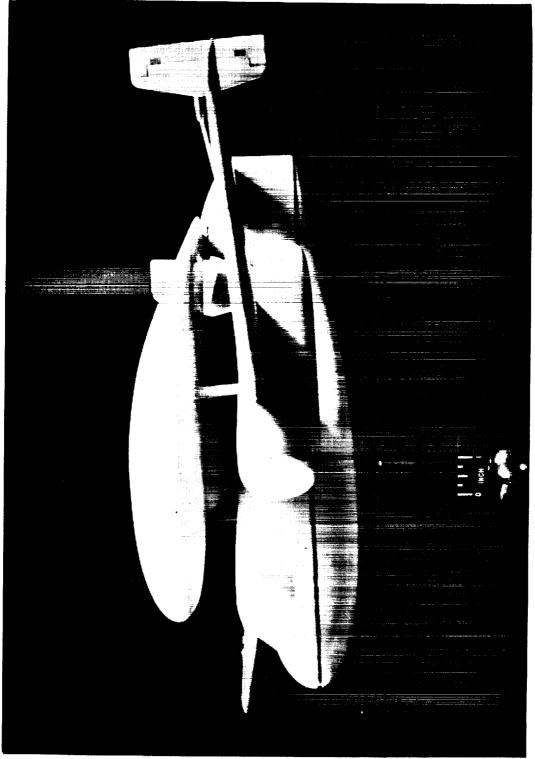
Airplane WF-2	Attitude Inverted	Spin direction simulated	Loading __2__ (see table__II__) Flight gross weight loading normal C.G.	
Slats	Altitude 30,000 ft.	Pilot's Right	Desired center-of-gravity position 26.3 percent c̄	Radome On

Model values converted to full scale　　　　　U-inner wing up　　　D-inner wing down

Ailerons ⅓ With

Top row boxes:

>373	
a½ , a½	

31	1U
408	0.26
½ , ½	

34 42	6U 6D
326	0.26
c½ , c1	
d>1½ , d>2	
e½, e¾, e1	

35 44	3U 4D
318	0.28
½ , ¾	

Elevator Full Up (Stick forward)

Elevator ⅔ Up.

31	0
318	0.28
c¾ , c¾	
d1½ , d>1½	

Middle row:

f — No Spin

28 36	1U
399	0.30
½	½

Ailerons Full Against (Stick Right, Controls Together) ← → Ailerons Full With (Stick Left, Controls Crossed)

32 42	3U 4D
326	0.30
1, 1	

Elevator Full Down (Stick Back)

Bottom row:

f — No Spin

g | gh — No Spin

>416	
ai1½	

31	1U
358	0.37
1½	1¾

Footnotes:

a Recovery attempted before model reached final steep attitude.
b Oscillatory spin, range or average values given.
c Recovery attempted by rudder reversal to 2/3 against the spin.
d Recovery attempted by rudder movement to neutral
e Recovery attempted by rudder reversal to 1/3 against the spin
f Model entered a vertical dive.
g Two conditions possible.
h Model entered steep erect glide.
i Model recovered in a steep erect glide.

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

Fixed slot

28.95"

7.70"

11.40"

W.L. 3.33

Fuselage reference line

6.34"

.93"

17.80"

Figure 1.- Three-view drawing of the 1/30-scale model of the Grumman
WF-2 airplane. Center-of-gravity position indicated is for the
flight gross weight with normal center-of-gravity loading.

L-326

Figure 2.- Photograph of the 1/30-scale model of the Grumman WF-2 airplane.

L-57-751

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MEMORANDUM 4-24-59L

for the

Bureau of Aeronautics, Department of the Navy

FREE-SPINNING CHARACTERISTICS OF A 1/30-SCALE

MODEL OF THE GRUMMAN WF-2 AIRPLANE*

TED NO. NASA AD 3134

By Henry A. Lee

ABSTRACT

The investigation was conducted in the Langley 20-foot free-spinning tunnel on a dynamic model to determine the spin and recovery characteristics of the Grumman WF-2 airplane. The results indicate that satisfactory recoveries from erect spins will be obtained by full rudder reversal to against the spin accompanied by movement of the elevator to at least two-thirds down. Inverted spins of the airplane will be satisfactorily terminated by full rudder reversal to against the spin and by neutralization of the longitudinal and lateral controls.

INDEX HEADINGS

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*Title, Unclassified.